

# VU Research Portal

## Historico-cultural sustainability and urban dynamics: a geo-information science approach to the Algarve area

de Noronha Vaz, E.; Nijkamp, P.

2009

### **document version**

Early version, also known as pre-print

[Link to publication in VU Research Portal](#)

### **citation for published version (APA)**

de Noronha Vaz, E., & Nijkamp, P. (2009). *Historico-cultural sustainability and urban dynamics: a geo-information science approach to the Algarve area*. (Research Memorandum; No. 2009-21). Faculteit der Economische Wetenschappen en Bedrijfskunde.

### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

### **Take down policy**

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

### **E-mail address:**

[vuresearchportal.ub@vu.nl](mailto:vuresearchportal.ub@vu.nl)

# **Historico-Cultural Sustainability and Urban Dynamics – A Geo-Information Science Approach to the Algarve Area**

PN312EdNV

Eric de Noronha Vaz

New University of Lisbon  
Institute for Statistics and Information  
Management  
Campus de Campolide  
1070-312 Lisbon  
Portugal  
[ericvaz@serviorg.com](mailto:ericvaz@serviorg.com)

Peter Nijkamp

VU University  
Faculty of Economics and Business  
Administration  
De Boelelaan 1105  
1081 HV Amsterdam  
The Netherlands  
[pnijkamp@feweb.vu.nl](mailto:pnijkamp@feweb.vu.nl)

## **1. Dynamic Urban Spaces and their Historico-cultural Heritage**

Over the past decades, the history of human geography in many countries has shown a tendency towards more urban patterns of living accompanied by an extension of people's action radius. Urbanization has become a worldwide phenomenon. This is exemplified in Europe, with an average urbanization rate of 70 to 80 percent. We observe not only a rise in 'urbanity', seen from the perspective of urban or metropolitan population densities, but also new tendencies towards more distant suburbanization or de-urbanization patterns. Even rural areas are increasingly being turned into accessible areas that are well connected to urban centres and also display urban lifestyles. 'Accessibility' and 'mobility' are key words in a modern dynamic space-economy, not only at intraregional scales but also at interregional and even international scales.

The dynamics in settlement and mobility patterns is prompting a wide array of research and policy questions on socio-economic equity, spatial disparities, growth differentials and sustainable development. Nowadays, many cities and regions exhibit a tension between competitive growth strategies and sustainable community strategies (e.g. environmentally-benign initiatives, preservation of socio-cultural heritage). Consequently,

in various countries, cities and regions have currently become battlefields between growth advocates and conservationists. As well as being global command and control centres (Sassen 1998), urban spaces appear to be concentrations of ecologically- and historically-valuable assets which reflect a memorable past.

The socio-economic, political-geographic and cultural-scientific history of the dynamics of places and localities on our earth is reflected in their historico-cultural heritage. This patrimony comprises cultural assets, such as old churches, palaces, museums, urban parks, historical architecture of cities, or landscapes of historical interest. Historico-cultural heritage also includes archaeological sites, which sometimes not only have a local value but may have a worldwide significance (e.g. Pompeii). All these assets mirror the rich history of a city or region and are a permanent source of scientific and cultural inspiration for researchers, planners, and the public at large. This ongoing interest in socio-cultural heritage originates from two sources: (i) a society in motion is prompted to ask new questions about its past in order to better understand the choices to be made concerning its future pathways; (ii) the progress in scientific research and in research techniques (e.g. infrared technology) allows researchers to investigate cultural assets in a different way that often leads to novel findings.

These developments have also generated new departures for research in the cultural and archaeological sciences, as is witnessed by the following quotation: “Archaeology has traditionally possessed strong conceptual divides between data collection and data analysis, manifested most obviously between excavation and post-excavation activities” (p.36) (Conolly and Lake 2006). Actually, the emphasis in modern archaeology is not so much on excavation and material reconstruction of a historico-cultural asset, but increasingly on data analysis using GIS and spatial modelling techniques (Renfrew and Bahn 2004). Exploratory research is increasingly giving way to contextual and explanatory modes of research based on advanced data analysis. For example, the geographic identification of the position of observation towers on the walls of ancient cities or the search for vestiges of carbonized animal bones (‘blue collar research’) is nowadays followed by massive data analysis linking these findings to research outcomes elsewhere (‘white collar research’). These changes in research style call for creative modes of new analytical investigation. In this context, Schiffer (2004) argues:

“Human behaviour consists of activities, which can be aggregated by the investigator to create analytic unities at many scales. Virtually every activity consists of interactions among people and one or more technologies. Along with technologies for procuring raw materials and preparing food, there are, for

example, religious, social, recreational and political technologies, which enable people to interact with plants and animals, other people, and, as Walker (2001) has pointed out, even supernatural entities” (p.579).

Thus, research on historico-cultural assets in an urbanized society is increasingly characterized by modern digital data analysis.

The present paper will address research and policy issues on sustainable development in the Algarve region, Portugal. This area used to be a peripheral natural area with rich flora and fauna, but in recent decades its pleasant climate has attracted massive flows of foreign tourists, to the extent that the entire coastal zone of the Algarve shows clear signs of being an urbanized environment. This new development may endanger the historical and natural character of the areas whose cultural assets date back to the period of the Phoenicians, Romans and Moors. Its unique physical geography has led to a specific environmental, agricultural, architectural and social constellation whose roots can be found in the Neolithic period. The socio-historical complexity of this area calls for sophisticated research methods in order to unravel the location and functions of different civilizations, their cultural complexity, and their local identity.

The research for our Algarve case study has three characteristics:

- Strategic: identification of geographic patterns and historic remains to trace the historic patrimony of this area;
- Scientific: use of modern GIS and satellite information complemented with cellular automata approaches to better map out and examine historical and modern artefacts;
- Human-historical: tracing the behavioural and social interaction patterns of ancient civilizations in connection with modern development in the area.
- The tools used in our research are:
  - Database design and conversion into shapefiles using DB4;
  - Spatial analysis in combination with GIS technology (ArcMap®);
  - Topographical reference using ortho-photomaps from satellite information including archaeological data (see Westcott and Brandon 2000).

Clearly, the use of geo-information science tools is a prerequisite for sophisticated applied research on the history and the present situation of the area concerned. As Gillings and Goodrick (1996, ¶1) put it on their Internet Archaeology online article: “GIS is increasingly being seen as much as a place to think as a simple data management and mapping tool.”

Our paper is organized as follows. Section 1 explains the importance of understanding the dynamics of change in urban spaces and the need to

develop sustainable policies while preserving the historico-cultural heritage. Next, Section 2 discusses the recent possibilities of geo-science and their diverse capabilities of coping accurately with regional management. In Section 3, we describe recent technological developments in GIS that can lead to a better understanding of the usefulness of Cellular Automata and spatial data analysis as research tools for dealing with spatial sustainability. Section 4 will then describe the Algarve as a laboratory of interesting possibilities for analysing cultural heritage ventures in a European context in combination with the application of GIS technology. On the basis of GIS data, we next develop a scenario of urban growth in the Faro-Olhão area in the Algarve, recognizing the current state of endangerment with a practical emphasis on the possibilities of GIS analysis and cognition. Finally, we will outline future directions and challenges of GIS as a toolbox for monitoring urban growth from a spatial and cultural resource perspective.

## **2. Geo-science Tools**

GIS technology was originally developed as a set of sophisticated digital mapping tools, but has gradually moved into a real scientific discipline, viz. geo-science, which forms an integrated set of ICT-based methods and tools (including satellite information, remote sensing, cellular automata) which lies at the heart of modern detailed spatial and dynamic analysis of objects of all kinds (see, e.g., Clarke and Hoppens 1997, Engelen et al. 1999). Its user-friendliness and polyvalence makes geo-science an appropriate methodology for a wide variety of dynamic spatial analyses, e.g. objects in urban planning, traffic management, archaeological investigations, architecture and cultural heritage (see, e.g., Wheatley and Gillings 2002, Conolly and Lake 2006). Geo-science has derived its current popularity not only from its advanced representational possibilities in space and time, but also – and in particular – from its high predictive potential (see, e.g., Syphard et al. 2004, Al-Kheder and Shan 2005, Cabral 2006). This also holds for cultural heritage and archaeological site management (see, e.g., Sebastian and Judge 1988, Kvamme 1999, Warren and Asch 2000, Ebert 2004, Verhagen 2007, Box 2005, Pontius and Chen 2006).

Since the Malta Convention on the management of cultural heritage resources, geo-science has assumed a prominent position in presenting, mapping and analysing cultural and archaeological assets, a tendency which in recent years has in fact been strengthened as a result of the policy

need for sustainable local development. The overall idea is that cultural assets should not lose their scientific relevance in the case of urban or infrastructural development, so a balance has to be found between archaeological or historico-cultural interest, on the one hand, and socio-economic and spatial development on the other, an intention also clearly outlined in the Valetta Treaty. The use of satellite information, in order to uncover spatial land-use and land-cover, has proven to be extremely fruitful for our in-depth analysis of the problems concerned here. The technologies involved are manifold and include such applications as Landsat, Thematic Mapper, SPOT or Corona. The various applications were summarized by Montufo (1997) as follows:

“The results obtained by using satellite imagery for a survey of ancient rural land-use patterns are highly dependent on three factors:

1. The existence of the remains for former land-use patterns in the study area.
2. The existence of other patterns that can be confused with ancient land use patterns.
3. The ability of the system to record and discriminate between patterns” (p.81).

The usage of satellite imagery for GIS is evident. Satellite imagery is of extreme importance to help locate and understand the dynamics of land use/land cover, as well as to represent and have a clear and as sharp as possible notion of space and morphological surroundings. Hence, one could consider satellite images as the principal asset used in a GIS for spatial understanding and relevant spatial analysis that can provide support for later decision making. Thus, Remote Sensing in Archaeology anchors itself in the very essence and usage of GIS in archaeology – it can be used either for research, to answer questions regarding past human activity or for management, to support in a proactive way decision making and cultural heritage preservation.

It is generally recognized that the increasingly intensive use and modification of the landscape resulting from modern demands for efficient infrastructure and land use (agricultural production, mining, energy sources, leisure/tourism facilities) exerts growing pressure on cultural heritage in the landscape (Grøn and Loska 2002, p.4).

Satellite monitoring for cultural heritage management is an important issue that has been a very important tool in a rapidly changing world, helping better and more sustainable governance. “Satellite images are an excellent tool to monitor change in large natural and/or cultural sites” (Hernandez 2002, p.104), in which the quick perception of the ongoing reality and the state of the site can easily be assessed at low cost and with no specific restrictions or boundaries. Hence, size and limit of observations do not depend as much on politics, but rather on scientific intuition. Not

only does satellite imagery represent a tool that on a periodic basis can monitor any change and occurrence but it can also be seen as a data set that allows predictive modelling which may be an asset for regional and local planning. The advantages of Satellite Remote Sensing can be synthesized as follows (Hernandez 2002, p.103):

- It offers a valuable tool to assist conservation activities;
- All information is exactly localized and gathered in one tool;
- Information can be updated continuously;
- Better decision making by spatial analysis;
- Possibility of direct extraction of topographic and thematic maps for use on the actual terrain.

The ‘Cultural Cycle’, as explained by the Department for Culture, Media and Sports of the United Kingdom<sup>1</sup>, can very well be adapted to the circumstances of monitoring cultural heritage via remote sensing satellite imagery. The Cultural Cycle has 6 key dimensions of action: Creation; Making; Dissemination; Exhibition/Reception; Archiving/Preservation; and Education/Understanding. Satellite Remote Sensing, used to monitor cultural heritage, can have an impact on the last three dimensions, in which the objectives could be understood as follows:

- Reception: reception of the satellite data with cultural heritage information for analysis;
- Archiving/Preservation: importing results of imagery in a GIS, Land cover/Land use analysis to monitor change and actively preserve;
- Education/Understanding: dissemination of results to create social awareness of the importance of cultural identity.

The importance of monitoring cultural heritage sites with satellite imagery is crucial, as it is a form of understanding ongoing change and has a direct impact on preservation issues, which is so important in a very quickly changing world. Thus, strategies can be taken more reliably and more systematically. Remote sensing via satellites and its growing technology is a tool for change.

It is clear that quite substantial investments are required for cultural heritage and archaeological research in urban areas. As such, the available database is no more than a mere reference of what originally might have existed in a given area. The gap between the originally existing sites and the currently identified ones may change (Joukowsky 1980). One of the most interesting possibilities in Cultural Resource Management in a GIS context is after all the capacity to predict change or dynamic behaviour given a set of rules or parameters. In this sense, predictive modelling is of

extreme importance and should be largely used to facilitate the stakeholders' decision making process, and has great potential as a tool for archaeologists working in cultural resource management (Hill et al. 2007).

### **3. Cellular Automata, GIS and Cultural Heritage: Methodological Challenges**

The human need to understand the environment has always been a constant in the endeavour to gather knowledge. Since the dawn of history, human beings' aspiration to go beyond the commonsense rules to understand patterns and interactions has brought them the capability to survive. Not only has population adapted to nature, but discovering technology has amazingly quickly developed it in such a way, so as to gradually allow the construction of a new kind of nature: that of virtual reality and the era of the machines. The origin of this new system is no more than yet another of the ongoing reflexes of nature, and can be described according to Ludwig von Bertalanffy's 'General System Theory':

There exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or 'forces' between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general (von Bertalanffy 1950, p.32).

Intrinsically, this statement calls out for a convergence of different areas, sculpting a new kind of science that finds its roots in biology, physics, geography, sociology, and many other areas, that together have contributed to the construction and fundamental notions of Systems Theory.

In fact, a system can be defined as an ongoing interaction of reciprocal influences between different agents (Legrand 1991). It becomes quite obvious that with the existing advances of technology and computer aided processes, these agents can be *virtually* represented, and their 'behaviour' specified by a set of variables in such a way that one can create behaviourist non-linear approaches to estimate and predict patterns in an in vitro environment in the computer. In any recreation of any agent that simulates behaviour, time is a crucial variable that deals precisely with the dynamics of change of the agent in a temporal context. Thus, the models that allow the creation of such agents and the context that allows their patterns to be studied must be a consequence of what are called dynamic models, in which the temporal factor represents a crucial factor to allow the study of the dynamic and its motion. Hence, Agent-Based Models are



the logical step to combine dynamic models with intuitive agents that relying on a set of variables allow predictive behaviour. These specific kinds of models have their branches in areas of the computational sciences and find a vast utility in many related areas. As they are capable of reflecting quite clearly the behaviour of groups and biological variables, they have been used quite extensively in the social sciences. After all, in these circumstances “computers offer a solution to the problem of incorporating heterogeneous actors and environments, and nonlinear relationships (or effects)” (Lansing 2002, p.284).

One of the sub-forms of exploring and modelling these systems that evolved as the consequence of understanding these agents was Von Neumann’s first cellular automata. Cellular Automata (CA) are discrete mathematical models that consist of a grid of cells that allow interaction of variables within the designated system, involving the variable time, thus representing a dynamic system in which patterns of behaviour may be observed. The applications of CA are manifold and are often used in any area which studies a system that is inherently dynamic and wants to predict a set of behaviours given a number of rules with a temporal basis. Because of their intrinsic nature (a grid-based system with a specific number of cells) they are quite adaptable to a Geographical Information System (GIS) environment. Given the necessary software and programming experience or attachable models, one can adapt CA easily to the context of a GIS and do predictive multi-temporal dynamics of change on a spatial basis.

An important task of GIS is to monitor ecological change, in order to make a direct impact on change and sustainability. The combination of GIS with CA allows change of land use to be precisely tracked and assessed and may be an important guide for regional policies and stakeholders. In this sense, one of the important uses of CA in a GIS context is the possibility to measure and predict urban growth in a given area. This context is not new, as it had originally become important in the 1960s (Wilson 1974). But, it is with the development of computer hardware and software that CA has finally provided the possibility of giving reliable results that can also explain dynamics visually, if interpreted in a GIS. Although it is obvious that urban growth and increase of land use cover is inevitable, nevertheless, the analysis and interpretation of results can have a direct impact on how best such change can be oriented. CA must be seen in this context as a positive tool for monitoring dynamics towards firm results which can answer a question such as “What if urban growth continues to evolve under unchangeable conditions?” This simple question and its complex answer may be assessed with Urban Growth CA and is a step towards the preservation of fauna, flora and

cultural heritage resources. Artificial areas, like cities, will continue growing, but perhaps with the help of technology in a more humane and sustainable form.

#### **4. Algarve: A GIS Laboratory for Cultural Heritage**

The Algarve is a region with heterogeneous morphology, which can be divided into three distinct areas: littoral (the coastline of the Algarve, which as a result of the rise of the tourist industry since the 1960s has largely been transformed into a number of medium-sized urban areas); barrocal (the central area of the Algarve, often related to agriculture); and the interior (composed of mountains that separate the Algarve from the rest of Portugal to the North).

Rapid urban growth took place in the Algarve from the mid-1960s with the explosion of the mass tourism industry in the area. At that time, the bewildering choice of tourist activities immediately endangered important natural and cultural assets, which consequently deprived the Algarve of some of its once natural charm, transforming the littoral areas into landscapes of bricks and mortar. This new landscape, characterized by hotels, towering over a once ecological scenario is still visible today, as tall buildings extend along the shores of the Atlantic Ocean.

While the tourist industry continues to flourish in the Algarve area, many important ecological topographic characteristics were lost forever in the chaotic 1960s and 1970s that the Algarve experienced. Now, almost 40 years later, in an integrated European context where sustainability has become an important issue, stakeholders are trying as best they can to manage the still important ecological and cultural assets in order to preserve the important landscape characteristics that have made the Algarve special since the time of the Phoenicians. A good example of this endeavour is PROTAL (Programa Regional de Ocupação do Território do Algarve – Regional Programme of Territorial Occupation in the Algarve), which was reviewed in 2006. This programme is in effect a manifesto of the willingness to provide sustainable land use organization and its needs in this region.

Europe's natural tendency of population growth threatens a dire scenario for small regions such as the Algarve: as much as initiatives such as PROTAL may try, urban growth is an unavoidable consequence, and sustainability has to cope further with larger and more complex urban sprawl which, if not monitored accordingly, obviously jeopardizes the landscape.

This seems to be the case in the vicinity of the Algarve's district capital, the city of Faro, which, with a population of slightly over 58,000 according to CENSUS 2001, experienced a total tourist population for the municipality of Faro of 204344 individuals (INE 2006), that is, an increase of 3.5 times during its summer months. Even though tourism may be beneficial for the regions' growth and has proved to be the main source of employment, if it is not correctly managed such a seasonal swelling of population may be detrimental for sustainable development.

Furthermore, not only seasonality but also employment opportunities are contributing directly to city growth, and this may clearly be seen on the periphery of the district capital Faro. An example of such growth is the city of Olhão, just 5 km from Faro, which is increasingly becoming the capital's dormitory city, as a result of more affordable prices as well as recent building opportunities.

This, as well as easy access to Faro and other important cities such as Portimão, Albufeira and Vila Real de Santo António, have made Olhão a booming city which is extending mainly along the main roads on Faro's periphery.

GIS tools and spatial data inventories such as CORINE Land Cover may be important tools to analyse with some accuracy the urban growth phenomena, as data inventories reveal with CORINE Land Cover 90 and CORINE Land Cover 2000 the important dates of growth between Faro and Olhão, which may be dynamically assessed because of the existence of two distinct moments in time.

Homer's *Odyssey* is proof that his Heroes already knew the west of the Mediterranean (Maia, 1987).

But the other cliff, thou wilt note, Odysseus, is lower – they are close to each other; thou couldst even shoot an arrow across – and on it is a great fig tree with rich foliage, but beneath this divine Charybdis sucks down the black water  
(*Odyssey* XII, 102).

This unique region, extending over almost half of the Iberian Peninsula from as far as the southern lands of the river Tagus to Spanish Andalusia, was settled by many civilizations.

The region of the Algarve belonged to the Tartessos region, and was described by the geographer Strabo (63 BC – 24 AD, in his renowned work *Geographica*, which gives an accurate historical and social description of the Ancient World. The existence of different civilizations is manifold and archaeological evidence remains from as early as the times of the Celts (Maia, 1987) as well as abundant Palaeolithic remains, are visible (Veiga, 1887). During the Roman occupation, Augustus redrew the administrative boundaries in the first century, and the region became a part

of the province of Lusitania. It was only much later, at the beginning of the 12th century that Lusitania became segmented into a number of different provinces. One of those provinces was the Al-Garb, a name from the Moorish, meaning “The Occident”. Later, in 1250 the Al-Garb province was conquered by the Christians and became the region of the *Algarbe* and was incorporated in the sovereignty of Portugal. The heterogeneous morphology of the present-day Algarve was quite similar in the times of the ancient Algarve.

Turdetanium is a prosperous country with all kinds of products and in large quantity. This richness is doubled by exports. The existing estuaries serve as routes of transportation which is carried out by tiny boats that enable the connections from the river deltas to the open sea. The abundance of rivers and estuaries makes almost the entire region navigable

(Strabo, *Hispania Antiqua*, II, 1).

Strabo also gives us a clear idea of the inhabitants’ behaviour in Roman times, mentioning also some of the major cities at that time:

The inhabitants built their cities with great proximity to their rivers and estuaries. Those cities are Asta, Nabrisa, Onuba, Ossonoba, Mainoba and a few others. The existing channels that connect those cities also ease the already abundant commerce. Commerce is carried out with the entire Italy and Rome being quite accessible by boat (Strabo, *Hispania Antiqua*, II, 5).

The city of Faro, formerly known as Ossonoba, dates back to the 4th century BC. Regarding Ossonoba, in the last 100 years an archaeological debate has taken place concerning its exact location. No one knows for sure whether this ancient city was located on the existing urban area of Faro or rather, on the outskirts of the current city.

This dilemma deserves special attention from the archaeological and scientific community, as Ossonoba with already pre-Roman influence became the capital of the Roman *civitas* (vast Roman administrative region). This rich multicultural background of the Algarve, as a heterogeneous region of the Mediterranean, bestows on it a richness of cultural heritage, intertwined with Phoenician, Roman, Moorish and early Christian archaeological history.

The region as a whole, with its multi-cultural identity, has in itself become a very interesting study: European policies and urban growth characteristics apply easily, and its cultural heritage is a very visible attraction which should be protected actively as otherwise it may be endangered.

## 5. Foci of Algarve Sustainability Challenges

### Introduction

Nowadays the Algarve area faces many sustainability challenges, which call for solid GIS-based research. The literature (Clarke and Hoppens 1997, Syphard 2004, Al-Kheder 2005, Cabral 2006) strongly recommends the usage of Euclidian distance factors (urban proximity, road proximity), as well as morphological characteristics (slope, land use) for predicting urban growth which is stochastically assessed. As tourism seems to be a key growth factor in the Algarve region, distance from the International Airport of Faro was taken into account, as well as proximity to the University campus. Social leverage was analysed using CENSUS data per parish (*freguesia*).

Table 1 illustrates the data inventories used for the creation of our urban growth model. It is this combination of different important geographic inputs that will enable an accurate assessment of urban change in the studied area. Road information was digitized from the Portuguese Digital Map at 1:500000 and georeferenced as polyline shapefile layers in ArcGIS (Table 1).

Figure 1 explains the overall methodological process used, showing that the multiple data chosen for urban growth assessment will constitute our suitability map that, with linear information of growth change between CLC90 and CLC2000, will lead us to a first estimation of urban growth towards a known temporal frame: the year 2008. This prediction is done using Cellular Automata iterations based on a Markovian transition matrix as will be explained later. Should the projection for 2008 prove to be accurate, assemblage of data will allow estimation for 2038. We will next in Subsection 5.2 describe the underlying database for our study (Fig. 1).

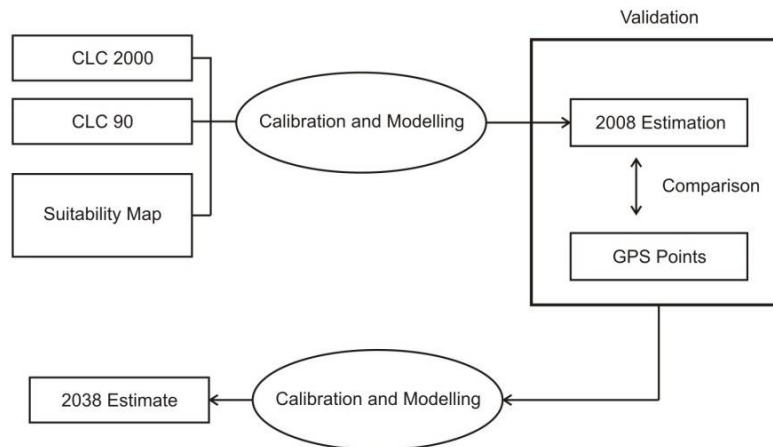
**Table 1.** Data chosen for urban growth model

Data Layer	Source	Original Projection	Used for
Environmental data			
Algarve DEM 90m resolution	SRTM (Shuttle Radar Topography Mission - NASA)	UTM	For creation of slope
Slope	SRTM (secondary data)	Lisbon Hayford- Gauss	Significant Layer for APM
Portuguese Administrative Chart	Portuguese Geographic Institute	Lisbon Hayford- Gauss	Definition of Municipality and Freguesias Boundaries
Land Use for Portugal	Requested from Portuguese Environmental Institute, belonging to CORINE Land Cover 90 and 2000 Project	Lisbon Hayford- Gauss	Significant Layer to understand land use / land change between CLC90 and CLC2000
Roads	Digitized on screen from Carta de Portugal Digital 1:500000 scale – Portuguese Geographic Institute	Lisbon Hayford- Gauss	Road distance is critically analysed as an important factor for network proximity between Faro and Olhão
Social data			
CENSUS 1991 and CENSUS 2001	CENSUS 1991 and CENSUS 2001		Used to balance weight factors among freguesias and tendencies of growth

## 5.1 Spatial data inventories and urban growth

The CORINE (Coordination of Information on the Environment) Land Cover (LC) project started on 27<sup>th</sup> June, 1985 as a programme that would address the following issues: state of individual environments; geographical distribution and state of natural areas; geographical distribution and abundance of wild fauna and flora; quality and abundance of water resources; land cover structure and the state of the soil; quantities of toxic substances discharged into the environment; and a List of Natural Hazards (EEA) (Fig. 1).

In this sense, CLC can be summarized as “an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community” (Official Journal L 176, 6.7.1985 - European Environment Agency). With the mapping of CLC2000, besides the already manifold usage of CLC, we have the advantage of assessing two distinct moments in time and, thus, an evaluation of changes in landscape and land use can be obtained by the analysis of multi-temporal images (Prol-Ledesma et al. 2002).



**Fig. 1.** Methodological approach for projecting urban growth prospecting

Following the very important notion that dynamic modelling needs time-based support and that CLC usage was a standardized opportunity to assess change, we could not think of a more convenient method of assessing the change of urban areas than comparing the urban areas of Faro-Olhão in the CLC90 with the CLC2000 series. CORINE Land Cover has a general nomenclature which can be divided into five distinct types, namely: Urban, Agriculture, Forest, Wetlands, and Water bodies. All of these five types are present in the Algarve area. Creating a cross-tabulation matrix for both CLCs, we could compare CORINE Land Cover 90 and CORINE Land Cover 2000 at a glance, and understand the possible changes within both time frames. From this comparison we drew the following conclusions:

1. Most of the agricultural areas have changed to urban areas;
2. A lesser quantity of forest areas have changed to urban areas;
3. Some forest areas have changed to agriculture areas;
4. A few agriculture areas have changed to forest.

Therefore, the matrix results indicate some clear and simple conclusions which are considered quite typical in an actual environmental context: urban areas expand on man-made soils, while unploughed land becomes ploughed and normally changes from Forest to Agricultural. Agricultural changes to Forest may be related to abandonment or to governmental incentives for Forest preservation. As no such incentives were planned for the Algarve region, the most probable reason for the change is related to agricultural abandonment. This information is of crucial significance to support a linear notion of urban growth tendency. It is this tendency that will manifest itself as a propensity of change which can be applied as a rule for our urban growth. Table 2 shows a cross-tabulation matrix for assessing changes in the different land-use classes between CLC90 and CLC2000 (the columns represent CLC90, while the rows represent CLC2000).

**Table 2.** Cross-tabulation matrix between CLC90 and CLC2000

	Urban	Agricultural	Forest	Wetlands	Water bodies	Landuse Change
Urban	100.00	1.07	0.29	0.10	0.00	1.46 %
Agricultural	0.00	98.69	0.85	0.00	0.00	0.85 %
Forest	0.00	0.15	97.87	0.00	2.58	2.73 %
Wetlands	0.00	0.09	0.39	99.90	1.25	1.73 %
Water	0.00	0.00	0.59	0.00	96.17	0.59 %



bodies

On the other hand, Table 3 suggests the possibilities of conditional change to different land use types based on Markovian transition rules for an 8-year estimate, which allows us to estimate how much will be changed in 2008

**Table 3.** Markovian Transition Probability Matrix

	Urban	Agricultural	Forest	Wetlands	Water bodies
Urban	85.00 %	3.75%	3.75 %	3.75%	3.75%
Agricultural	13.21 %	83.89%	1.79 %	1.11%	0.00%
Forest	2.28% 15.08	6.75%	9% 0.00	3.10%	4.67%
Wetlands	%	0.00%	% 12.3	84.92%	0.00%
Water bodies	0.00%	0.00%	1%	5.94%	81.75%

## 5.2 Urban growth trends for the Faro-Olhão area

A suitability map may be understood, as a consequence of present spatial interpretation, to recognize possible future land use scenarios. An initial rehearsal regarding urban growth tendencies was done by generating a comparison of CLC90 and CLC2000 with respect to urban growth change which allowed us to assess the existing growth for the area linearly. The insertion of further variables, such as recovered population data, distance weights to roads, urban centres, as well as international airport distance and university location, prove to be key economic drivers for future urban growth in the Algarve region. This may be seen in Figure 2, where a suitability map results from the selection of the variables and consequently, the addition of the different layers, arriving at a conclusion about the propensity for urban growth in the studied area.

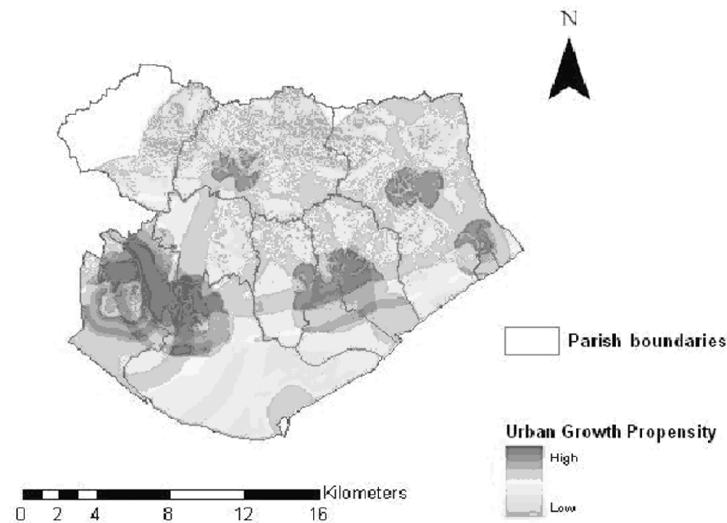
This weighted and normalized information, as shown in Annex 1, allowed us to create a suitability map for the most probable urban growth tendencies in the forthcoming years. It is thus an example of prospective planning regarding existing urban growth, anticipating, as well as coping with, the natural tendencies of important factors that govern urban sprawl.

It can be clearly seen that a tendency for further growth around the periphery of Faro is likely to happen. As CENSUS data have pointed out,

the most probable districts of further growth are on the outskirts of the district capital. In recent decades, proximity to the National Road 125 and to the University of the Algarve campus have been shown to be important factors for continuing urban growth. The overall trend appears to be a continuing growth of Faro-Olhão, as well as the possible growth of other urban nuclei such as Estoi and Quelfes.

Using IDRISI as a software tool with easily usable Cellular Automata (CA), linear CORINE Land Cover cognition, and the calculated suitability map will all allow us to assess the tendency of urban growth more accurately and thus understand the necessity for commitment towards the preservation of the cultural landscape which may occur in the near future.

Clark Labs – IDRISI comprises the perfect tool for accurate assessment for CA. CA transition rules are related to a set of possibilities constituted by iterations of Markovian probability matrixes (if the CA\_Markov module is used, as is the case in our study). The advantages of using Markovian probability matrixes related to CA mainly concern the possibility of measuring different land use changes that are supported in the initially generated matrix (Table 3). This is a considerable advantage, as it shows the capacity of these matrixes to cope with different kinds of land use trends and their transformation.



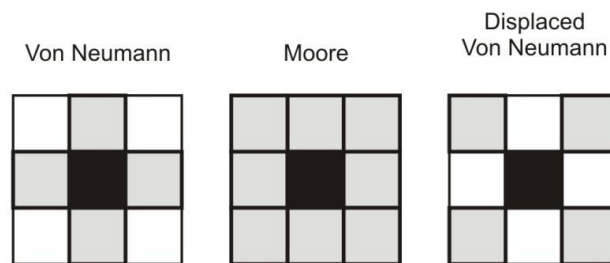
**Fig. 2.** Suitability map for urban growth

Four important principles will allow cells to iterate, thus originating a CA. These principles (Batty, 2007) create the concept of a CA for our region of study. Firstly, the land use of the region of the Algarve is represented in raster format with a specific dimension of equal-sized cells that relate to others by a given proximity or adjacency. Secondly, our cells can only take one state at a time, that is, one cell can only change into urban, agricultural, wetlands or water bodies and never into two of the classes simultaneously. Thirdly, changes in a cell depend on the existing *neighbourhood* of the particular cell, influenced by our fourth condition, the propensity to change previously calculated on our suitability map. The basic cell thus relates to its local *neighbourhood* and gains a spatial dimension which may be perfectly adequate for land use prediction and urban growth. An example of CA neighbourhoods may be observed in Figure 3.

Our urban growth model forecasts urban growth based on CLC90 and CLC00 information for two distinct time frames: 2008 and 2038. The reason for projecting the 2008 land use is related to the importance of validating the assumptions and choice of variables in our initial input. In this sense, two hypotheses occur: (i) our model shows enough accuracy

and we are thus prompted to model the 2038 land use situation and urban growth tendencies; or, (ii) inaccuracy leads us to reframe our pool of variables and their choice in order to better grasp the tendencies of urban growth in the Algarve.

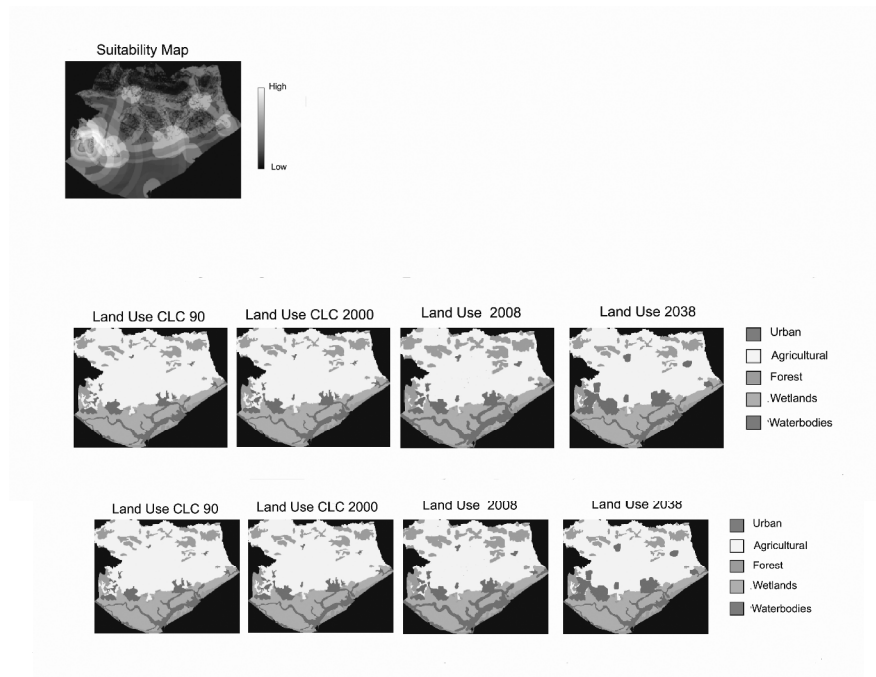
The validation of the 2008 urban growth was done on the actual terrain, using 100 surveyed points to target urban and non-urban areas. As a result, Producer and User Accuracy were tested, showing us the overall accuracy of our modelled 2008 land use for urban areas.



**Fig. 3** Example of Cellular Automata Neighbourhoods

Our 2008 forecast generated a result of global exactitude of 93 per cent and a kappa statistic of 86 per cent. These encouraging results allowed us to continue with our forecast of the 2038 land use/land change panorama. User Accuracy is a result of the division of the number of correctly classified pixels in each category by the total number of pixels that are classified, and indicates the probability that a pixel classified in a given category actually represents that category on the ground (Lillesand et al. 2004).

A clear tendency of urban growth around the periphery of existing urban centres seems to exist (Figure 4). Thus, rather than the appearance of new urban centres in the Faro-Olhão area, growth seems to occur depending on attractiveness factors such as proximity to the University and to the International Airport. Those reasons seem to be the explanation for extended growth particularly along the west side of the Faro perimeter. Previously small and almost inexistent agglomerations at the beginning of the 1990s will inevitably form larger areas with some endangerment of the natural and historic landscape.

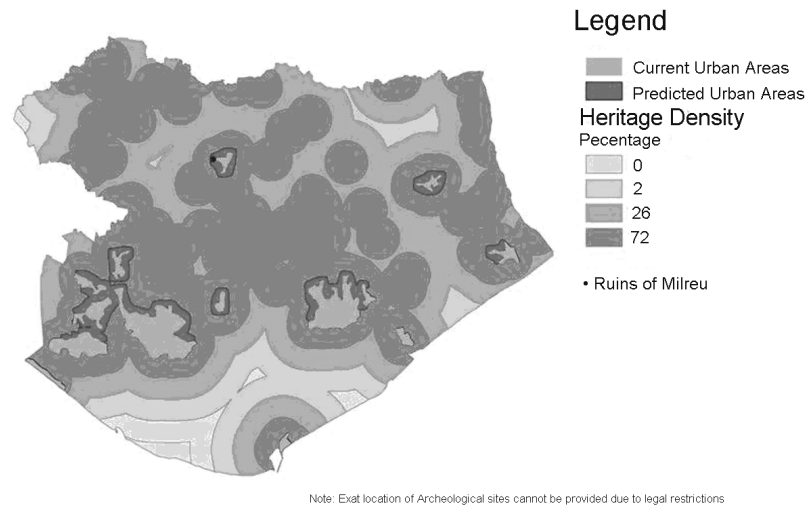


In the mid-19<sup>th</sup> century, Estácio da Veiga actively studied the heritage which remained from prehistory in the Algarve. Later he founded the first Archaeological Museum, which could be considered as the first academic initiative of archaeology in the Algarve. Prehistory and protohistory had already gained some relevance as archaeological records, but the clearly visible Roman and Moorish influence seemed to gain weight due to the growth of archaeological Romanticism which was important at the time when Estácio da Veiga was gathering information and continuing an, alas unfinished, fifth volume to his *Antiguidades Monumentais do Algarve*. (Veiga 2006)

It was the initiative of the Instituto Português do Património Arquitectónico (IPPAR) in 1989 that for the first time resulted in an archaeological map of Portugal, which summarized some of the important archaeological remains in the region. Based on the *Carta Arqueológica de Portugal*, as well as on other bibliographical research, we were able to compare a total of 43 archaeological sites regarding their proximity to urban growth. The results were obvious: of our 43-site sample, 72 per cent were located within a radius of less than 1 km from urban areas, while 26

per cent were located within a maximum of 2 km radius, against only 2 per cent which are located within 3 km of the urban perimeter. This indeed is an alarming scenario, as our comparison was based on the generated land use for 2008. As illustrated in Figure 5, regarding the proximity of our archaeological remains to the urban area in our 2038 projection, the average expansion of up to 1 km in the next 30 years is endangering and could destroy 72 per cent of the region's archaeological sites if no monitoring and planning takes place. Among the analysed sites, prehistoric site locations, Roman necropolises, Roman villas and Moorish artefacts were taken into account. One of the sites directly targeted for eminent endangerment are the Ruins of Milreu, which were classified as a National Monument in 1910 and are considered to be one of the largest Roman Villas in Portugal.

Figure 5 represents a combination of site propensity to change to urban use and urban growth prediction in an attempt to visualize the possible endangerment of the cultural heritage.



**Fig. 5.** Site propensity to change to urban use and urban growth prediction

## 5.4 Policy Lessons and Conclusions

It has become clear that the Algarve is an area of the utmost importance regarding a long tradition of historico-cultural heritage. GIS tools with their capability to assess spatial information and cope with large-enough databases from various sources seem to be an important pillar for strategic decision making support, as well as for regional planning and monitoring heritage endangerment.

Urban growth, an unavoidable reality, may jeopardize a fragile cultural background which shares valued patrimony. The spatial cognition of such archaeological sites and better notions of urban growth and sprawl based on urban growth models and spatial analytical processes have proved to be important tools for an ongoing research agenda of historic and socio-cultural heritage protection in the Faro-Olhão area.

It is our hope that, with the increasing accuracy of urban growth models, the historico-cultural heritage endangered by the growth of urban peripheries may be better analysed, leading to sounder and more sustainable cities which would never lose the asset of their cultural identity, but pass it on to future generations to cherish.

## Notes

<sup>1</sup> <http://www.culture.gov.uk/NR/rdonlyres/50E5EC89=7A5E-4B33-8CFA>

## References

- Al-Kheder S, Shan J (2005) *Cellular Automata, Urban Growth Simulation and Evaluation – A Case Study of Indianapolis*. GeoComputation 2005, University of Michigan, Michigan.
- Batty M (2007) *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals*, The MIT Press, Cambridge, MA.
- Box P (1999) *GIS and Cultural Resource Management: A Manual for Heritage Managers*. UNESCO, Bangkok, UNESCO.
- Cabral P (2006) *Étude de la Intersection Urbaine par Télédétection, sig et Modélisation, Mathématiques et Applications aux Sciences Sociales* École des Hautes Études en Sciences Sociales, Paris.
- Clarke KC, Hoppens S (1997) *A Self-modifying Cellular Automaton Model of Historical Urbanization in the San Francisco Bay Area*. Environment & Planning B, vol. 24, 1997, pp. 247-261.
- Conolly K, Lake M (2006) *Geographical Information Systems in Archaeology, Manuals in Archaeology*, Cambridge University Press, New York.
- Ebert D (2004) *Predictive Modeling and the Ecology of Hunter Gatherers of the Boreal Forest of Manitoba*. BAR S1221, Archaeopress, Oxford.
- Engelen G, Geertman S, Smits P, Wessels C (1999) *Dynamic GIS and Strategic Physical Planning Support: A Practical Application*. In: J Stilwell, S Geertman and S Openshaw (eds) *Geographical Information and Planning* Springer-Verlag, Heidelberg.
- Gillings M, Goodrick G T (1996) *Sensuous and Reflexive GIS; Exploring Visualization and VRML*. Internet Archaeology I, internet: <http://intarch.ac.uk>
- Grøn O, Loska A (2002) *Development of Methods for Satellite Monitoring of Cultural Heritage Sites*, Technical Report NIKU, Norwegian Space Centre, Oslo.
- Hernandez M (2002) *Use of Satellite Imagery and Geographical Information Systems to Monitor World Heritage Sites*. World Heritage Paper 10, UNESCO.
- Hill B, Devitt M, Sergeyeva S (2007) *Understanding Past and Future Land Use*, *ArcUser Online*, <http://www.esri.com/news/arcuser/0507/pastlanduse.html>, April-June, ESRI.



- Homer (1984) *The Odyssey*, Translated by A. T. Murray, Loeb Classics – Harvard University Press, Norwich.
- INE (2006) *Anuário Estatístico da Região do Algarve - Statistical Yearbook of the Algarve Region*, Instituto Nacional de Estatística, Lisbon.
- Joukowski M (1980) *A Complete Manual of Field Archaeology: Tools and Techniques of Field Work for Archaeologists* Prentice Hall, Englewood Cliffs.
- Kwamme KL (1999) *Recent Direction and Developments in Geographical Information Systems*. Journal of Archaeological Research, vol. 7, no. 2, pp. 153-185.
- Lansing JS (2002) *Artificial Societies and the Social Sciences*. Artificial Life, vol. 8, pp. 279-292.
- Legrand G (1991) *Dicionário de Filosofia*, Edições 70, Lisbon.
- Lillesand TM, Kiefer RW, Chipman JW (2004) *Remote Sensing and Image Interpretation*, 5<sup>th</sup> Edition, John Wiley and Sons, USA.
- Maia MA (1987) *Romanização do território hoje português a sul do Tejo – Contribuição para a análise do processo de assimilação e interacção socio-cultural 218 a.C – 14 d.C*, PhD Thesis in Prehistory and Archaeology, University of Lisbon, Faculty of Letters, Lisbon.
- Montufo A (1997) *The Use of Satellite Imagery and Digital Image Processing in Landscape Archaeology. A Case Study from the Island of Mallorca, Spain*. Geoarchaeology, vol. 12, no. 1, pp. 71-85.
- Pontius GR, Chen H (2006) *GEOMOD Modeling*. In: Eastman JR (ed) *Idrisi 15: The Andes Edition* Clark Labs, Worcester MA.
- Prol-Ledesma RM, Uribe-Alcántara EM, Diaz-Molina O (2002) *Use of cartographic data and Landsat TM images to determine land use change in the vicinity of Mexico City*. International Journal of Remote Sensing, vol. 23, no. 9, pp. 1927 – 1933.
- Renfrew C, Bahn P (2004) *Archaeology: Theories, Methods and Practice*, Thames and Hudson, London.
- Sassen S (1998) *Globalization and its Discontent: Essays on the New Mobility of People and Money* The New Press, New York.
- Strabo (2007) *Geographica*, Translated by A. Forbiger, Marix Verlag. Wiesbaden.
- Schiffer MB (2004) *Studying Technological Change: a Behavioural Perspective*. World Archaeology, vol. 36, no. 4, pp. 579-585.
- Sebastian L, Judge J (1988) *Predicting the Past: Correlation, Explanation and the Use of Archaeological Models*. In: Judge WJ, Sebastian L (eds) *Quantifying the Present and Predicting the Past: Theory, Method and Application of Archaeological Predictive Modelin*, Government Printing Office, Washington DC.
- Syphard AD, Clarke KC, Franklin J (2004) *Using a Cellular Automaton Model to Forecast the Effect of Urban Growth on Habitat Pattern in Southern California*. Ecological Complexity, vol. 2, no. 18, p. 118-203.
- Veiga, S. P. M. E. da (1887) *Antiguidades monumentaes do Algarve. II*, Imprensa Nacional, Lisbon.

- Veiga S P M E da (2006) *Antiguidades monumentaes do Algarve – Tempos Históricos, Volume V* Câmara Municipal de Silves, Museu Nacional de Arqueologia, Loulé.
- Verhagen P (2007) *Case Studies in Archaeological Predictive Modelling*. ASLU 14, Leiden University Press, Leiden, the Netherlands.
- Von Bertalanffy L (1950) *An Outline of General Systems Theory*. *Philosophy of Science*, vol. 1, no. 2.
- Warren RE, Asch DL (2000) *A Predictive Model of Archaeological Site Location in the Eastern Prairie Peninsula*. In: Wescott KL, Brandon RJ, (eds) *Practical Applications of GIS for Archaeologists: A Predictive Modeling Toolkit*, Taylor and Francis, London.
- Westcott KL (2000) Brandon RJ *Practical Application of GIS for Archaeologists: A Predictive Modelling Kit*, Taylor & Francis, London.
- Wheatley D, Gillings M (2002) *Spatial Technology and Archaeology: The Archaeological Applications of GIS*, Taylor and Francis, London.
- Wilson AG (1974) *Urban and Regional Models in Geography and Planning* Wiley, Chichester.